Synoptic-Scale Forcing Caused Stratospheric Sudden Warming of 2006

Major stratospheric sudden warmings (SSWs) result from large changes in the mid-winter stratospheric circulation in response to upward propagating energy from the troposphere. The relevant tropospheric forcing systems are often large-scale, blocking-ridge, weather patterns. However, our work shows an example in which a smaller-scale, non-blocking, upper tropospheric disturbance provided forcing for the major SSW of January 2006.

We examined the major SSW of January 2006 using meteorological fields from *GEOS-4* (Goddard Earth Observing System) analyses. Early January 2006 found the stratospheric polar vortex weaker than normal and displaced off the pole because of earlier minor warming events. On 16–17 January, a tropospheric weather system over the North Atlantic amplified at upper levels as it moved under the lower stratospheric vortex. The resulting upper tropospheric ascent produced cold temperatures at ~100 hPa as the altitude of the 360 K potential temperature surface rose from typical midlatitude values of 12.25 km to over 14.5 km at this time. As this large amplitude, upper-tropospheric perturbation moved eastward at ~12 m s^{-1}, directly disturbing the lower stratospheric flow, it launched large-amplitude Rossby waves into the stratosphere. In the mid-stratosphere (~30 km altitude, ~10 hPa or ~1100 K) this upward-propagating wave energy turned equatorward, producing subtropical wave breaking by 18 January. Finally, the advection of tropical midstratospheric air to the pole associated with the wave breaking led to the major SSW on 22 January. Forecast studies using the NOGAPS–ALPHA (Navy

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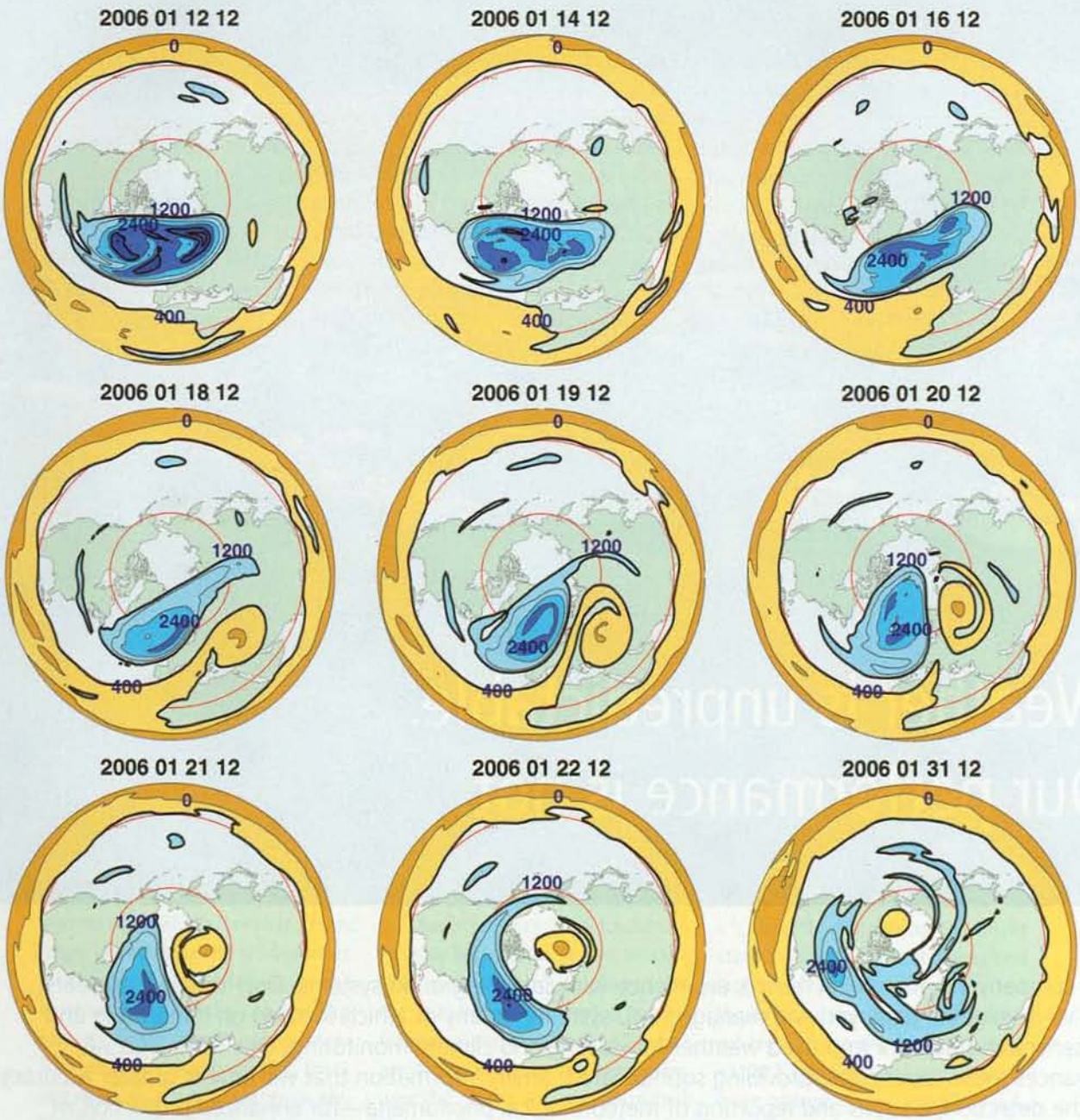
Operational Global Atmospheric Prediction System–Advanced Level Physics High Altitude) model confirm that correctly modeling the intensifying upper-level weather system in the North Atlantic was necessary to obtain the major SSW. On 16–17 January 2006 this system was the only major upper tropospheric disturbance, making its identification as the forcing region for the major SSW unambiguous.



The 1100 K (just above 10 hPa) potential vorticity (PV) field during the big SSW of 2006. Contour interval is 400 PV units (PVU). Red circles are at 20° and 60°N latitude, and the Greenwich meridian (0° longitude) points down. Dates are year, month, day, and hour (UTC). The vortex (blue shading, over 2800 PVU on 12 Jan) was off the pole and relatively stationary from 12–14 Jan. By 16 Jan, however, it had propagated east and strong subtropical wave breaking had begun. By 20 Jan, normally tropical values of PV formed an anticyclonic circulation (shaded in tan and brown) at 60°N, creating the major warming. This low PV anomaly (less than 400 PVU) subsequently moved across the pole. Note: The 800 PVU contour has been removed to simplify the figure.

Further investigation is needed to determine what fraction of major SSWs are initiated by localized upper tropospheric forcing such as this. We highlight a similar example of an eastward propagating weather system over the North Atlantic that forced a major SSW in January 2003. As in January 2006, a locally elevated 360 K potential temperature surface was associated with changes in the lower stratospheric flow, prior to subtropical wave breaking in the midstratosphere, followed by the major warming. In addition, it is noted that, though the dynamics are more complicated, a similar eastward propagating upper tropospheric disturbance occurred in the South Atlantic prior to the Southern Hemisphere major SSW of September 2002.

Examining long-term reanalyses should find additional examples of local upper tropospheric forcing and subtropical wave breaking. Diagnostics such as the midlatitude 360 K heights will be fundamental for comparisons with the January 2006 warming as well as compositing and predictability studies.—LAWRENCE COY (NAVAL RESEARCH LABORATORY), S. ECKERMANN, AND K. HOPPEL. *"Planetary Wave Breaking and Tropospheric Forcing as seen in the Stratospheric Sudden Warming of 2006," in the February* Journal of the Atmospheric Sciences.

ECHOES

"I'm sure most of us don't understand exactly how it works. But I still thought it was worthwhile."

—ANDY KURLANSKY, owner of Everybody's Pizza in Atlanta, Georgia, speaking about a new carbon trading plan that has made the city's Virginia Highland district a "carbon-neutral zone"—the first such area in the country, according to its participants. A local environmental organization called Verus Carbon Neutral Partnership established the project, which offsets the carbon emissions of 18 participating businesses in the popular shopping and dining neighborhood. Each shop owner in the project is charged an amount comparable to its business's emissions, and Verus uses the money to support a sustainable forest in rural Georgia that contributes to the removal of carbon from the atmosphere. "We spend 90 percent of our time explaining how it works," says Eric Taub, the founder of Verus, which is now approaching other communities about similar initiatives. (SOURCE: *Atlanta Journal-Constitution*)